HELICAL CERAMIC RESONATOR STRUCTURES

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ABSTRACT

Miniature coaxial ceramic resonators are widely used in mass produced filters for wireless systems. Additional reduction in size and weight can be achieved by using the proposed helical ceramic resonator structure. Any filter configuration realizable using coaxial ceramic resonators can also be produced using the new structure. In this short paper, the helical ceramic resonator design is described and sample filter structures are presented. The proposed resonator structure can be produced by using standard ceramic resonator technology and leads to substantial miniaturization of ceramic resonator filters.

INTRODUCTION

Continuing expansion of mobile communication systems has created a need for low cost, small size components to be used in compact and inexpensive hand held receivers / transmitters. The use of high dielectric constant ceramics to implement resonators and filters for these applications results in low cost, miniature components without compromising their electrical performance. Miniature coaxial ceramic resonators are presently produced in very large quantities by many manufacturers and are widely used in wireless communication systems. The main frequency range for these devices covers a low microwave range (RF) typically up to 3 GHz. Constant pressure from system manufacturers to further reduce the size of these elements led to development of very high dielectric constant materials > 100, since the size of a fully loaded coaxial structure is directly proportional to the square root of its dielectric constant.

Recently, dielectric-loaded single mode and dual mode helical resonators have been proposed to reduce the size of helical filters [1]. However, these resonators still require metal enclosures as in the dielectric resonators or in combline filters. Introduced here is a helical ceramic resonator structure similar to the traditional coaxial ceramic resonator. Together with the high dielectric constant material, the proposed helical ceramic filters can be made much smaller than the current miniature coaxial filters.

The basic idea for helical ceramic resonator is quite simple. However, the optimization of the proposed structure for performance and manufacturability is not obvious.

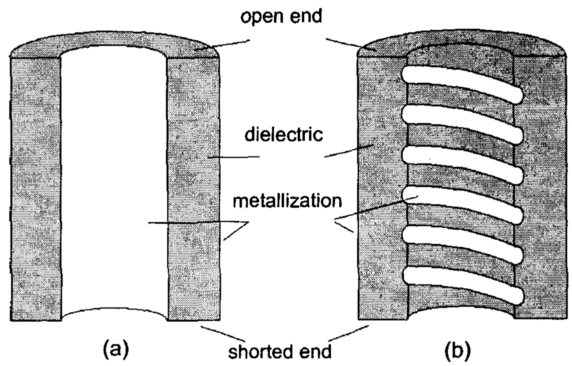

Fig. 1 – Cross-sectional view of two ceramic resonator structures: (a) conventional coaxial. (b) proposed helical.

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HELICAL CERAMIC RESONATOR

The basic design of the helical ceramic resonator is shown in Figure 1. The selected configuration features the "air" helix loaded on the outside with high dielectric constant material. This approach is compatible with the manufacturing of standard coaxial ceramic resonators, and the dielectric loading of the helical resonator operating in fundamental mode is most effective.

In the first order approximation, the length of the helical and coaxial ceramic resonators are both equal to the quarter-wave length scaled with the square root of the dielectric constant. However, the helix is a slow-wave structure and therefore has a much shorter wavelength than that of the coax [2,3,4]. Consequently, the helical ceramic resonator is much shorter than its coaxial counterpart.

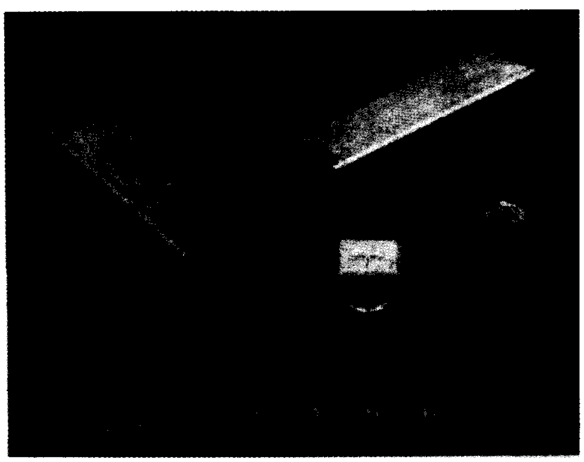

Fig. 2 – 142 MHz coaxial ceramic resonators are almost 6.5 times larger than the 120 MHz helical ceramic resonators.

The helical ceramic resonators under studied are in 0.5" x 0.5" x 0.5" cubes. The width of the helix is 0.05", the pitch is 0.1" and the dielectric constant of the ceramic is 80. Resonant frequency of the fundamental mode is calculated to be 990 MHz in air and 110 MHz in the dielectric using the standard formulas for helix [5]. Figure 2 is a photograph of the helical ceramic resonators comparing to coaxial ceramic resonators of similar resonant frequencies. The coaxial ceramic resonators (0.6" x 0.6" x 2.25") are at least 6.5 times larger than the helical counterparts.

EXPERIMENTS

The resonant frequency and unloaded Q of the ceramic resonators shown in Fig. 2 are measured using a weakly coupled transmission method. The measured unloaded Q of the coaxial resonator is 470 (Fig. 3), and that of the helical resonator is 55 (Fig. 4). However, the ratio of unloaded Q per volume remains about the same, which is not surprising because the unloaded Q is proportional to the energy stored in the resonator (i.e., the volume of the resonator). Since the unloaded Q of a helix is a strong function of the resonator diameter [5], and the helical ceramic resonator here is not optimized for its maximum Q, the unloaded Q of the helical resonator could probably be made higher.

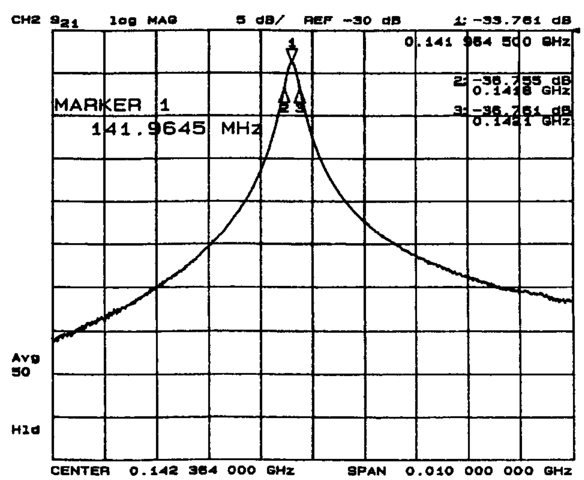

Fig. 3 – Measured unloaded Q of 470 at 142 MHz for a coaxial ceramic resonator.

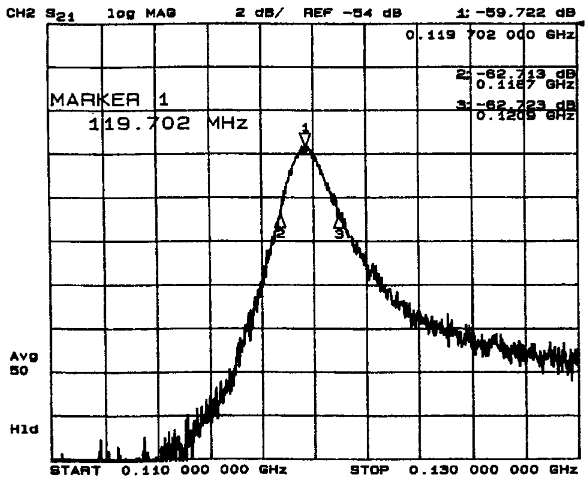

Fig. 4 – Measured unloaded Q of 55 at 120 MHz for a helical ceramic resonator.

With the helical ceramic resonators as building blocks, a large variety of filters can be constructed. Individual resonators can be either inductively or capacitively coupled together as in most coaxial ceramic filters, or manufactured in a single block of dielectric as in the mono-block ceramic filters (a dielectric version of the combline or interdigital filter). Figure 5 shows a dual helical resonator at 140 MHz, as compared to a commercial dual coaxial ceramic resonator at 900 MHz.

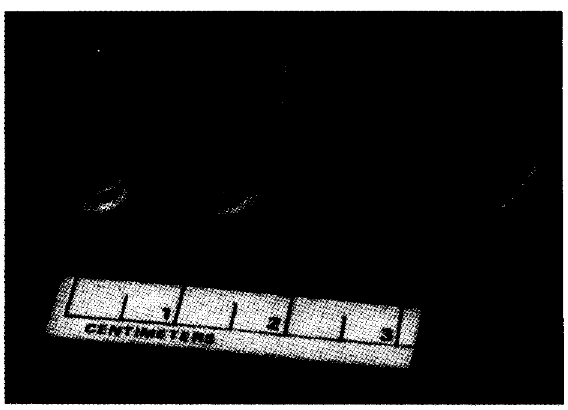

Fig. 5 – A dual helical ceramic resonator at 120 MHz, and a dual coaxial ceramic resonator at 900 MHz.

To demonstrate the feasibility of fabricating a filter out of the new resonators, a 2-pole filter is constructed by coupling two individual helical resonators with a lumped inductor. Input / output coupling are realized by directly tapping a copper wire onto the center conductor. The performance of the constructed coaxial and helical filter is shown in Figures 6 and 7, respectively. The insertion loss of the 10% bandwidth coaxial filter is 0.44 dB, which translated to a filter Q of 110. The 20% bandwidth helical filter has an insertion loss of 0.52 dB, corresponding to a filter Q of 40. No attempt was made to maximize the Q factors in this experiment.

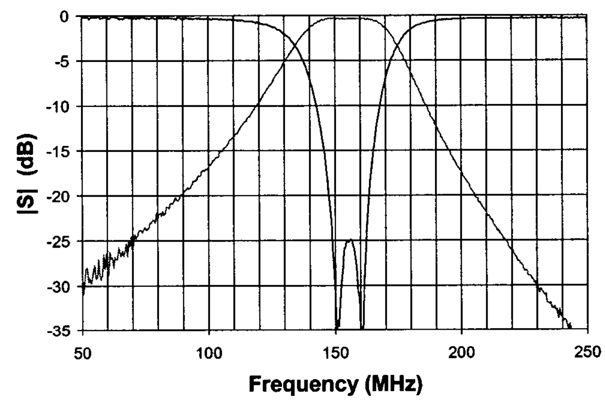

Fig. 6 – Measured return loss and rejection of a 10% bandwidth, 2-pole coaxial ceramic filter at 155 MHz.

In any filter structure, coaxial ceramic resonators can be replaced with the proposed helical ceramic resonators. One possible configuration of a generalized mono-block is shown in Fig. 8. Four different coupling schemes are illustrated. Coupling between resonators 1 and 2 is adjusted by a thru hole in the dielectric, with the coupling strength controlled by the diameter and the depth of the opening. Coupling between resonators 2 and 3 is achieved by the appropriate spacing between them, between resonators 3 and 4 by a printed circuit element, and between resonators 1 and 4 by a slot cut between them. Of course, any combinations of these coupling schemes would also be adequate. This particular layout takes advantage of non-adjacent cross coupling and hence can be used to realize a quasi-elliptical function filter.

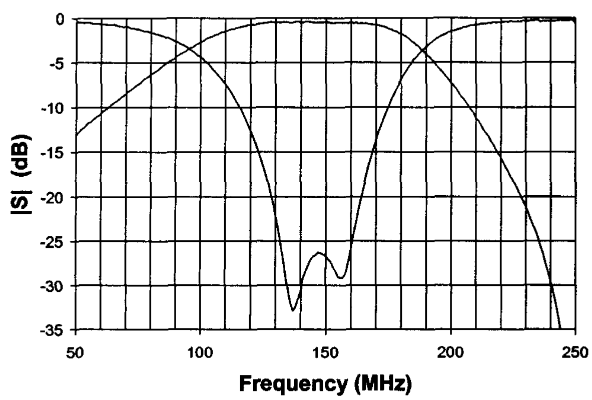

Fig. 7 – Measured return loss and rejection of a 20% bandwidth, 2-pole helical ceramic filter at 147 MHz.

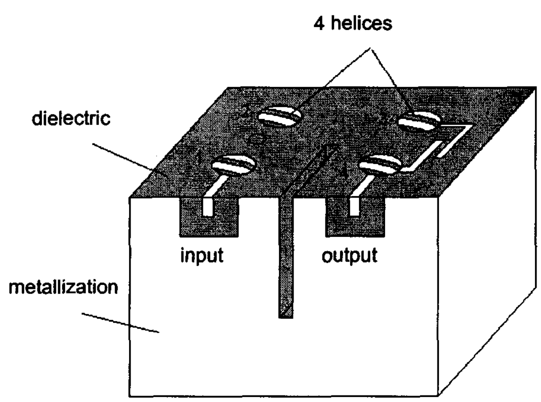

Fig. 8 – A generalized ceramic mono-block filter utilizing 4 helical resonators. Four different coupling schemes are illustrated.

CONCLUSIONS

The proposed helical ceramic resonator, when fully optimized, can replace existing coaxial ceramic resonators in most of wireless applications. The benefits include size and weight savings without significant cost impact.

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REFERENCES

[1] S. J. Fiedziuszko, R. S. Kwok, "Novel Helical Resonator Filter Structures", *IEEE Int. Microwave Symp. Digest*, pp. 1323-1326, 1998.

[2] R. E. Collin, "*Field Theory of Guided Waves*", pp.637-640, McGraw-Hill, New York, 1960.

[3] J. R. Pierce, "*Traveling Wave Tubes*", D. Van Nostrand Co., Princeton, NJ., 1950.

[4] P. Vizmuller, "*Filters with Helical and Folded Helical Resonators*", Artech House, Norwood, MA., 1987.

[5] A. I. Zverev, "*Handbook of Filter Synthesis*", Ch. 9, Wiley & Sons, New York, 1976.